

Introductory Remarks: Microelectronics, Radiation, and Superconductivity

by Michael Gochfeld*

Among the costs of technology are health hazards that face employees and consumers. New advances in the highly competitive field of microelectronics involve exposure to a variety of hazards such as gallium arsenide. Small high-technology industries appear unprepared to invest in health and safety. Although stray electromagnetic fields are not a new development, researchers are beginning to assemble data indicating that such fields pose a significant cancer risk under certain circumstances. Data have been obtained on fields associated with power lines on the one hand and consumer products on the other. Although not conclusive, the data are sufficient to warrant carefully designed research into the risks posed by electromagnetic fields. Because the scientific issues require research, there is a need to make basic social value decisions that will determine which technologies will be developed and which ones may be set aside because of their danger at the present time.

Introduction

This paper focuses on the environmental implications of the microelectronics industry and superconductivity. Specifically, we will examine agents such as arsenic, nonionizing radiation, and stray magnetic fields. Note that researchers have argued persuasively for the universality of premarket testing, including the continued development of synthetic organic compounds. By contrast, the agents discussed in this paper have existed throughout the course of human evolution. We deal not with new agents, but with new ways of exposing ourselves to old ones as a consequence of new industries and products. As more people experience excessive exposure, it is clearly necessary to develop a suitable research agenda to better understand how these agents will affect us in the decades to come. We hope we can face new technologies without resorting to old and discredited approaches.

About 15 years ago we were called to evaluate a production facility of a major computer company. On our walk-through, the health and safety officer proudly announced that "Our floors are so clean we can eat off them." Eating off the floor is not usually high on the list of concerns for an occupational health specialist. Despite its clean floors, that company had a major problem with arsine exposure, a concern which persists today.

The hazards of nonionizing radiation, like beauty, are in the eye of the beholder. Several years ago a community in northern New Jersey evaluated an excess of adverse reproductive outcomes and attributed these to

microwave radiation because of the large number of microwave antennas present. The U.S. Environmental Protection Agency (EPA) radiation technician who made measurements at that village said, "I can't imagine what they were worried about, I saw all of those big white antennas on every hillside. It was one of the most beautiful sights I have ever seen."

We continually surround ourselves with a variety of electrical devices. Evidence reveals that we cannot be complacent about the health effects of stray magnetic fields and argues for technology to develop protective strategies now.

Overview: New Technologies and the Environment

We have heard chilling and compelling accounts of what the future (and, in part, the present) holds in store for us. We have learned that an eat-off-the-floor environment is not necessarily clean in all dimensions. We have learned of aspects of the physical-biologic interface that provide credence to the effects of low energy fields and that stray magnetic fields pose significant public health hazards. These are new and pervasive problems associated with emerging technologies and indicate what can be expected from technologies that are now barely imagined.

Twenty years ago a group of scientists, educators, economists, humanists, and industrialists met in Rome to discuss the predicament of mankind. The Club of Rome Report (1) critically examined the intertwined growth curves of global population, technology, resources, and pollution, and emphasized the need for limits to growth. Implicit in this report is the argument

*University of Medicine and Dentistry New Jersey-Robert Wood Johnson Medical School, Piscataway, NJ 08854.

that a fundamental change in values and approaches to these four elements is possible. Society has managed to brush away these conclusions, and the Club of Rome Report is all but forgotten, with the result that society continues to muddle its way up the various exponential curves.

Although both the source and nature of the health concerns and hazardous exposures involve scientific and technologic concepts, prevention of exposure will probably involve socioeconomic processes, therefore my predictions will concern the socioeconomic context of science and technology. Ever since the movies of Buck Rogers and their portrayal of the twenty-fifth century, scientific developments that are imagined far outstrip reality, but reality is impressive and sobering enough.

Predictions are that there will be fundamental changes in the relation between technology and society that will effect which and how technologies will be developed. These changes will emerge inevitably as our society continues its inexorable march towards the predominance of service sector employment. Society will learn to monitor and control its various exposures. There are significant questions as to how society will act with the new information it obtains.

Suppose that one of the technologies under discussion were found to cause some extremely unpleasant disease, let's say acquired immunodeficiency syndrome (AIDS). Would our society have the courage to do what we ask of our teenagers regarding drugs, "Just say no"? Would we have the will to turn our back on an otherwise promising and lucrative venture and to consider health of greater value? Many of us remember the preplastic bag era, and most of us are already wedded to computers. But not all of our technologic developments play such a fundamental role in the weave of society. Much of the technology is being developed primarily for recreational use. Recreational technology like recreational drug use may be too great a burden for society to tolerate.

Therefore, in the next 25 years, society will focus closer scrutiny on new technologies and will regulate them, not so much by law, but by permit. We are already seeing this in the inability to site hazardous waste incinerators, prisons, drug treatment facilities, and now AIDS clinics. NIMBY, the "not in my back yard" syndrome, has increasing, if sometimes chaotic, impact on technologic development, at least in North America.

To be sure, much technology will be exported to a developing world that is anxious to share in employment, regardless of environmental costs. However, the safety and health issues, for example, of stray magnetic fields, refer to products as well as facilities. Therefore, it is reasonable to ask whether we as consumers are willing to bear the added product cost of safe workplaces, sound products, and a clean environment.

The automobile manufacturers successfully convinced us that we were not willing to bear the added cost of air bags, despite the fact that during the period of the debate, new car costs nearly doubled. I am convinced they were wrong. It was simply a case of no one wanting

to be first to test the waters; in fact, consumers pay added costs for many items, why not health and safety?

Knowledgeable consumers of the future will insist on shielding of products for protection from nonionizing radiation and stray magnetic fields. Also, the company that manufactures a cheap, portable, and reliable field-strength meter for home use will certainly have a sizeable market.

The Temporal Framework: Long-Term Payoffs

Society has developed a *modus operandi* that rewards short-term payoffs. Environmentalists find it difficult to understand how so many irrational decisions can be made that severely impact air, water, soil, and health. How can long-term population and industrial growth be ignored? What happened to the Club of Rome Report? These vexing frustrations are answered simply by saying that people who make decisions see no payoff from weighing long-term consequences over short-term benefits.

In all cases, short-term payoffs can be readily counted. This applies not only to industrial decision making, but to government officials who will soon be out of office and therefore out of sight, as well as to academicians, who in the quest of tenure, develop careers around short-term rather than long-term research objectives.

An essential ingredient of socioeconomic change will be to increase the payoff for long-range analysis and decision making. The air bag was an example of short-term decision winning out over long-term goals. There was "nothing in it for me" to take a chance this year. Students find it hard to believe that the scientific wizards and technology giants of the late nineteenth and early twentieth century could have visited upon us the legacy of asbestos. They find it difficult to believe that 50 years ago people in charge of asbestos production made a decision to deliberately suppress information on the hazards of asbestos, thereby condemning more than 10 million people to excess asbestos exposure (2). Nearly 50 years elapsed before this conspiracy was discovered, and through economic manipulations the companies still have not paid for that decision. Equally revealing was the decision of Ford motor company that, after evaluating costs and risks, decided not to recall the explosion-vulnerable Pinto, but to pay the death benefits as needed (3).

One of the reasons we have such weak epidemiologic data on many environmental health issues is that the long-term prospective studies that yield definitive information are shunned by researchers and granting agencies alike. The 3-year grant cycle is probably the worst thing that could have happened to environmental research.

Therefore, I predict that there will be a return to career development awards in this field, specifically requiring investigators to tackle long-term projects. At

the same time, the fundamental academic structure will be reworked; it is difficult to say whether or not this will come from attempts by universities to break the tenure system; from the development of a parallel, financially attractive, long-term investigator track (such as the clinical investigator); or perhaps from lengthening the pretenure period from 6 to 10 years.

Incongruence: Profit and Burden

Perhaps the most serious problem confronting environmental health and safety arises because the people who make decisions over whether or not to invest in occupational health, in product safety, or environmental quality are not the people who bear the burden when those decisions prove damaging. A case in point is the cost of tobacco-related disease that is borne not by the tobacco companies, but is spread out over all of society and the health insurance industry. Compared to this health subsidy, the price support subsidy for growing tobacco is, if you will excuse the term, peanuts.

I predict that the major stride towards health and safety will be to achieve a congruence between profit and burden, to assess responsible parties fairly for the damage they cost. I predict that this will become institutionalized, making each industry assume its fair share of the cost burden, and ultimately this will replace an even more costly and capricious tort system, already under attack. Decision-makers will have a clear mandate for profit-burden analysis which must ultimately increase the number of environmentally sound decisions.

Premarket Testing

I predict that there will be close scrutiny and some form of premarket testing, not only for new products but for new forms of technology. We have heard that many new technologies are emerging or are just behind the curtain of time. We have also heard people say of existing technologies, "if only we had known." We don't want to hear that cant a decade from now, much less 50 years hence. Silbergeld (4) and Mazzochi (unpublished observation) have both noted that our society views hazardous materials and processes as innocent until proven guilty. That too will change in the decades to come. If we are buying new technologies then *caveat emptor*, let the buyer beware.

Community Control

Oversight must become a community responsibility. In the past 8 years communities have lost confidence in government's ability or will to protect, much less in the will or ability of the involved industry to self-regulate. Through civic action communities will develop exhaustive permit application processes. An industry may expect to post a bond prior to construction, a bond that will pay for the community to perform independent monitoring and to hire consultants as needed. The bond will also cover preventive and emergency maintenance to assure

that a facility will continue to perform according to specifications. I predict this will evolve first in the case of solid waste incineration, but the potential exists for this action will apply to a vast array of developments.

Far from viewing it as a disincentive to investment, the new high-tech companies are likely to find it attractive to negotiate swiftly with communities and get their facilities on line before their more reluctant competitors. Many industries have recognized that some competitors gain unfair market advantage by ignoring regulations, and this enlightened self-interest must be harnessed to create a climate that promotes investment in health and safety. Social development will be an important complement to research development. These new industries employ a small number of relatively highly-trained people, people who are much in demand and tend to jump quickly from company to company. To be competitive in wooing such employees, the high-tech industries will be located close to attractive residential areas and will therefore need to be clean in image and deed. For the microelectronics industry described by Edelman (5), this image will require a major change in outlook.

Several steps are necessary to assist communities in making wise decisions. We must define hazards of each technology during its development. We must identify meaningful end points. The ability to monitor is important particularly in the area of nonionizing radiation and magnetic fields. A highly sensitive, portable, broad spectrum, and inexpensive field strength monitor is still far in the future, and I place a high priority on the development of such instrumentation.

Risk Communication and New Technologies

Probably of greater importance in assisting the communities is environmental education and risk communication. Polls such as New Jersey's Eagleton-Star Ledger Poll (6) have repeatedly shown that the public is more concerned about environmental health issues than almost anything else. This concern stems in part from fear, in part from awe, and in part from the recognition of the pervasive impact of environment on health.

The new technologies carry with them hazards that are simple (e.g., arsenic) and complex (nonionizing radiation). Some can be measured accurately with relative ease (arsenic), others are extremely difficult and costly to measure (electromagnetic fields). The magnitude of hazard associated with these agents (particularly stray magnetic fields) is still controversial. Yet we must convey this risk to society and seek an intelligent solution. Scientists have traditionally decried the ability of the public to understand risk. In part this represents Homeric hubris or professional "over-weening pride."

There is ample reason to believe that the public can understand most of the conclusions of risk assessment. One may comprehend risk without understanding the biophysical effects of electromagnetic fields. A person who can evaluate why one doesn't draw to fill an inside

straight in poker has a good basis for evaluating risk. It is not that the public does not comprehend environmental risk, but that each person responds to his comprehension in diverse ways. Policymakers and regulators are often puzzled and frustrated that a community can be outraged by a 1-in-a-million cancer risk from dioxin in soil, yet blithely ignore a 1-in-a-thousand risk from radon. An individual must factor in individual issues and values, which population-based risk assessment cannot accomplish. Wolman (unpublished observation) gave us a good example of that, and a decade ago Lowrance (?) enumerated factors that influence the individual's perception of and response to risk. We focus our ire on villains; radon has no villains, but that will not be true for arsenic or magnetic fields.

We scientists sometimes complain that the public can't understand us. The public understands us quite well. They are confused only when we are confused. They see relationships that elude us. They go beyond our facts to factor in self-interest, and if they are less tolerant of uncertainty, it is because they must make a decision in which they have a personal investment. To a scientist more research is always needed, but an individual has to decide on the dangers immediately. Faced by overpowering uncertainty, the individual may legitimately take either a worst case approach on the one hand or may resort to denial on the other.

Gotsch and associates are developing an elementary school curriculum in environmental health education (8). Starting in kindergarten, children will incorporate ideas on health and safety into their everyday lives. I predict that in 25 years such curriculum components will be standard fare for all our school children (and adults as well). Children will learn about what constitutes health and disease. They will learn about factors that produce ill health; about risk factors; and, of course, about environmental quality issues. They will learn about recycling and toxic waste, about radiation, and overpopulation, as well as how to influence their own risk factors and health. They will be a far better prepared substrate for the socioeconomic changes that I predicted above, and perhaps, understanding dose and response more critically, they will make wiser decisions regarding environmental risk.

An Alternative Scenario

What if these predictions are not realized? Then I see a future that skillfully ignores the need for premarket testing, knowing full well that postmarket regulation is ineffectual. If it were not true (e.g., EPA deregistration of pesticides), it would be hard for us to imagine a society in which a regulatory agency must reimburse a manufacturer for a product that is found to be too hazardous. Technology will continue to advance by ignoring hazards and by fighting regulation. It will invest untold money in lawsuits to forestall regulations, to avoid complying with regulations, or to avoid paying penalties. We will continue to be dominated by the theme that technology advances by ignoring hazards.

Wishful Thinking and the Scientific Method

I would like to call attention to a serious thought disorder that pervades science, government, and industry. I call it "wishful thinking." This is a form of self-deception that allows one to see what one wishes and ignore what actually is. With wishful thinking one turns assumptions into facts. One hears the words "compatible with" and concludes "proven." A wishful-thinking risk assessor may see thresholds and prohibit extrapolation in every case, while another may see only linear no-threshold models as the rule. Some deny that humans and rodents have anything in common and automatically denounce interspecies extrapolations. Wishful thinking is an important source of bias that must be exorcised. Moreover, wishful thinking is not limited to self-deception, for it can be harnessed to deceive others as well.

Beyond a Shadow of a Doubt

Much progress in environmental health has been thwarted by the insistence on certainty as the basis for regulation. There is much confusion about certainty. It may be inappropriate draw on the example of tobacco at a meeting held in North Carolina, but the Tobacco Institute's effort to obfuscate the nature of the scientific method by obscuring the hazards of tobacco is a case in point. When the Tobacco Institute argues that there is still no real proof that smoking causes bad diseases, it systematically misrepresents the nature of scientific proof that is achieved by verifying over and over again certain results. The proper response to such misleading arguments is to take the opposite approach, for if there is no proof, neither is there any doubt.

Biological proof is not the same as mathematical proof. So-called biological "proof," "certainty," and "irrefutability" are achieved by repetition; by replication; by validating previous results with new approaches; and yes, by a measure of redundancy. For a scientist the link between tobacco and diseases is indubitably proven. We must deal aggressively in the same vein with other causal relationships that have been proven beyond a shadow of doubt. We must remember, as Sheps pointed out (unpublished observation), that we can act on evidence that is compelling, even when it is not yet irrefutable.

Science and Action

It was fascinating to learn that the Roper Survey found that to the public, the term "environmentalist" is not a term of opprobrium (9). I am concerned that a poll taken of toxicologists, not only in industry, but in academia and government, as well, might have shown the opposite result; this reflects a serious detachment of scientists from activists, which I predict must change in the decades to come.

We have heard it said repeatedly that scientists are

terrible at communicating to the public and that they ought to mind their business and stay out of government. Yet I would argue that, particularly when it comes to the side effects of technology, scientists can make excellent contributions to policy. Certainly they are no worse than the economists and lawyers to whom we have largely abandoned environmental policy. For scientists it is critical to be unbiased in the design of experiments, interpretation, and presentation of data. But this does not mean being dispassionate or disinterested about what one chooses to study. I predict, therefore, that scientists will play a more active part in the development of policy, and that policy considerations will increasingly shape the scientific agenda of the next century.

Conclusion

We cannot rely on legislators to turn data into law nor on regulators to turn law into deed. We need to develop a concerted effort to bring together investors, industrialists, environmentalists, the government, and the public. The investors will have to see a vested interest in health and safety; it has to become too costly to do anything bad. I predict that strong financial disincentives will be far more effective in protecting the environment than regulation, enforcement, and the courts.

The twenty-first century, with the added complexity of its technology and scientific literature, will open an expanded role for the scientist as communicator and policy analyst. I think society has become sophisticated enough to thwart my last pessimistic scenario, and this

change will be enhanced by the emergence of environmental education and risk communication. We know that we must rely on ourselves to use good judgment and to maintain eternal vigilance. But vigilance is exhausting, and environmental health in the twenty-first century will require an implementation of the knowledge gleaned over the mistakes of the past century, of which there have been more than enough.

REFERENCES

1. Meadow, D. H., Meadows, D. L., Randers, J., and Behrens, W. W., III. *The Limits to Growth*. Universe Books, New York, 1972.
2. Castleman, B. I. *Asbestos: Medical and Legal Aspects*. Law & Business, Inc., Clifton, NJ, 1986.
3. May, W. W. \$s for lives: ethical considerations in the use of cost/benefit analysis by for-profit firms. *Risk Anal.* 2: 35-46 (1982).
4. Silbergeld, E. K. Toward the twenty-first century: lessons from lead and lessons yet to learn. *Environ. Health Perspect.* 86: 191-196 (1990).
5. Edelman, P. Environmental and workplace contamination in the semiconductor industry: implications for future health of the workforce and community. *Environ. Health Perspect.* 86: 291-295 (1990).
6. Eagleton Institute of Politics. *Images III: A Report on the Quality of Life in New Jersey*. Rutgers, The State University of New Jersey, New Brunswick, NJ, 1985.
7. Lowrance, W. W. *Of Acceptable Risk*. William Kaufmann Inc., Los Altos, CA, 1976.
8. Baxter, R. H. Some public attitudes about health and the environments. *Environ. Health Perspect.* 86: 261-269 (1990).
9. Gotsch, A., and Kashclan, R. *Healthy Environment—Healthy MC: A curriculum for K-5*. Environmental Occupational Health Science Institute, Piscataway, NJ, 1989.